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DENSITY MEASUREMENTS OF MATERIALS USED IN AEROSOL STUDIES

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The density of various aerosolized materials used in experiments was determined using an autopycnometer. Materials included kaolin, TiO2, *Bacillus globigii*, ovalbumin, syloid, Arizona road dust (ARD), casein, and A1203. The Stokes diameter of the ARD varied from 0.25 to 23 µm. Agreement of the measured densities with known densities was established. Accuracy of the data is considered acceptable for our studies.

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PREFACE

The work described in this report was authorized under Project No. 622384/ ACB2, Non-Medical CB Defense. This work was started in September 1998 and completed in May 2000.

The use of either trade or manufacturers' names in this report does not constitute an official endorsement of any commercial products. This technical note may not be cited for purposes of advertisement.

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DENSITY MEASUREMENTS OF MATERIALS USED IN AEROSOL STUDIES

1. INTRODUCTION

An Autopycnometer, Micromeritics Model 1320, was used to measure the density of materials that are aerosolized during various tests at the Aerosol Sciences and Technology Laboratory at the U.S. Army Edgewood Chemical Biological Center. The materials include both agglomerated and/or non-agglomerated particles. For non-agglomerated particles, a measurement of the density gives the particles' absolute density, sometimes called real or true density (ASTM 1997).[1] For agglomerated particles a measurement of the density may refer either to the absolute density or the envelope density. The absolute density of a porous particle is sometimes called the skeletal density (PsS and Micromeritics 1998).[2] The envelope density is based on the particle's volume, including internal voids.

Data on particle densities are important for converting geometric diameter to aerodynamic diameter. Instruments such as the Coulter Particle Counter measure a particle's equivalent volumetric diameter. To determine the particle's aerodynamic diameter one must multiply the Coulter equivalent volumetric diameter by the square root of the particle's density. In the case of a non-spherical particle, a shape factor correction (Baron and Willeke 1992)[3] is required. Similarly, a particle diameter measured with a microscope is the particle's cross sectional area equivalent diameter. It can be converted to an aerodynamic diameter using the square root of the density of the particle in addition to a spread factor for liquid particles (Baron and Willeke 1992)[3] as well as a shape factor for non-spherical solid particles.

Particle densities were measured in our study using a pycnometer. This type of instrument is used extensively in industry and academia both for quality control and for measuring the density of many types of porous and non-porous materials (B. Russell 1999).[4] Examples include calcined coke (ASTM 1997),[1] soils (Univ. of ME 1999),[5] open and closed cell foams (Quantachrome 1999),[6] polyethylene beads, and film and foamed or cellular plastics, glass, rubber, and metal (PsS and Micromeritics 1998).[2]

Many types of pycnometers exist and vary from relatively simple and inexpensive instruments for measuring fluid density, such as the Mettler Toledo pycnometer (Mettler 1998)[7] to the more complicated Micromeritics Autopycnometer Model 1320 (Micromeritics 1984),[8] which is suitable for measuring the density of porous particles. The latter was selected for our measurements. Although complicated, the instrument offers a convenient approach for determining particle density.

2. EXPERIMENTATION

The Autopycnometer Model 1320 (Micromeritics 1984)[8] is completely automated and operates by compression and expansion cycles of the chamber that contains the material. A null condition is first established before making the density measurement of a material. The density is determined by placing a known mass of the material in the autopycnometer chamber, dialing the weight of the material on the chamber, and pushing the run button. The volume of the material is determined by the instrument and density is calculated (mass/volume) and displayed on the instrument. Details are given in the manufacturer's operating manual (Micromeritics 1984).[8] Accuracy of the volume measurement is about $\pm 0.01\%$.

Condensed vapors, particularly water vapor, can significantly distort the density measurements as cautioned by the manufacture of the Autopycnometer Model 1320 (Micromeritics 1984).[8] Density measurements were therefore made when the particles were removed from their containers, labeled Room Conditions in the table, and after the particles had been dried in an oven at 83 °C (Bg was dried in the oven at 41 °C), labeled Dried Conditions in the table.

3. RESULTS

The density measurements are summarized in the table.

4. CONCLUSIONS

The Autopycnometer Model 1320 (Micromeritics 1984)[8] provided a convenient method for measuring the density of various particles. Accuracy of the data is considered acceptable for our studies.

Table. Density Data Measured with an Autopycnometer

Material (Descriptions given below)	Density Room Conditions g/cm^3	Density Dried Conditions g/cm^3
Kaolin	2.56	
TiO_2 (Kronos 2073)	4.22	-
Bg – old DPG* (not washed)	1.70	
Bg – old DPG*, washed	1.70	1.54
Bg - spray dried	1.78	
Bg – new DPG	1.41	
Bg- new DPG	1.36	1.33
Bg – made at ECBC	1.51	1.43
Ovalbumin – Jet Milled 2x	1.41	1.36
Syloid 244	2.82	2.08
**ARD 0-5 µm	2.92	2.63
**ARD 5-10 µm	2.76	2.65
**ARD 10-20 µm	2.83	2.71
Casein	1.30	1.23
Al_2O_3 - stokes diameter = 0.25 µm	4.14	3.98
Al_2O_3 - stokes diameter = 3 µm	-	3.82
Al_2O_3 - stokes diameter = 5 µm	-	3.86
Al_2O_3 - stokes diameter = 6 µm	-	3.94
Al_2O_3 - stokes diameter = 9 µm	3.99	3.92
Al_2O_3 - stokes diameter = 14 µm	-	3.92
Al_2O_3 - stokes diameter = 15 µm	-	3.96
Al_2O_3 - stokes diameter = 17 µm	3.95	3.90
Al_2O_3 - stokes diameter = 23 µm	3.93	3.92

*DPG: Dugway Proving Ground
**ARD: Arizona road dust, also known as AC Fines.

Description of materials listed in the above table:

<u>Kaolin[1332-58-7]</u>
Hydrated aluminum silicate, particle size 0.1 – 4 µm. Sigma Chemical Co., P.O. Box 14508, St. Louis, MO 63178.

TiO_2 [13463-67-7] (Kronos 2073)

TiO_2 = 97%, Yield 47.7%. Reported density by the manufacturer = 4.2 g/cm^3. Density (Handbook of Chemistry and Physics)[9] is 4.26 g/cm^3 for the colorless tetragonal form (natural rutile) and 4.17 g/cm^3 for the white rhombic form. Density results reported by Hinds (1982)[10] for TiO_2 is 4.3 g/cm^3.

Bg: *Bacillus subtilis var niger (Bacillus globigii)*

Material contains live, viable *Bacillus subtilis var niger* (*Bacillus globigii*) spores. Ingredients: Dried *Bacillus subtilis var niger* (*Bacillus globigii*), fermentation products, silicon dioxide. Lot No. 19076-03268. Date of manufacture: 19 July 1996.

Ovalbumin [9006-59-1]

Grade II, crude, dried egg white, Sigma Chemical Co., P.O. Box 14508, St. Louis, MO 63178.

Syloid 244

Material Safety Data Sheet, W.R. Grace & Co., Davison Chemical Division, Baltimore, MD. Chemical name, synthetic amorphous silica, ingredients: amorphous silica and absorbed moisture, CAS Registry No. 63231-67-4 (Silica Gel), Apr 1982.

ARD (Arizona Road Dust)

Obtained from Donaldson Co., Inc., Tulsa, OK. Material Safety Data Sheet, 29 CFR 1910.1200, OMB No. 1218-0072, Powder Technology Inc., Burnsville, MN, Jan 1991. Major components: SiO_2, Al_2O_3, Fe_2O_3, Jan 1991.

Casein[9000-71-9]

From bovine milk, purified powder, Jet milled two times, Sigma Chemical Co., P.O. Box 14508, St. Louis, MO 63178.

Al_2O_3

Gobain Industrial Ceramics, Speciality Ceramic Grains Division, Worcester, MA)
The Handbook of Chemistry and Physics[9] report the density of Al_2O_3 to be 3.965 g/cm^3 for the colorless hexagonal form and 3.97 g/cm^3 for the colorless rhombic crystalline form. Density of aluminum oxide reported by Hinds (1982)[10] is 4.0 g/cm^3.

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